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SPECIFICS OF DESIGN AND SERVICE OF HIGHLY EFFICIENT GLASS-MELTING FURNACES FOR SHEET FLOAT-GLASS

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Data on the improvement of the main technical and economical parameters of glass-melting furnaces in the leading countries and at the Salavatsteklo company are given. The authors consider the issues of upgrading the furnace design and operating regimes, which can increases the thermal and technological efficiency of furnaces, extend their campaign, and improve product quality. It is demonstrated that the optimal variants of refractory brickwork and thermal insulation of the most critical structural elements of the furnace substantially increase the furnace reliability.

The constant progress in tank glass-melting furnaces for float-glass used by leading world producers is obvious. In the past 30 years the main technical and economic parameters of furnaces have substantially improved (Fig. 1), which is supported by the following data: specific glass output per heated surface area has grown from 1500 to 2500 kg/m^2 per day, specific heat consumption has decreased from 2000 – 2100 to 1450 – 1500 kcal/kg, the campaign duration has extended from 4 – 5 to 10 – 12 years, and the quality of glass has improved substantially (the number of such defects as scale, blisters, or cords has decreased from 8 – 10 to 1 – 2 units/ton of glass produced).

The specified parameters for the glass-melting furnace No. 1 at the Salavatsteklo JSC have not yet reached the world level, however, they have improved perceptibly as well: the specific glass melt output up to 1800 kg/m^2 per day, the specific heat consumption to 1650 kcal/kg, the campaign duration to 7 years, and the number of defects to 3 – 4 units/ton of glass. The listed parameters obviously are below the world parameters, however, the long-term experience of operating glass-melting furnaces makes it possible to set the goal of rapidly reaching the world-level technical and economical parameters in the production of sheet float-glass and at the same time increasing 1.5 times the production capacity.

The most significant targets in upgrading the glass-melting process include:

– equipping furnaces with up-to-date wide-table batch and cullet loaders via the frontal hoppers, which ensures more intense melting of batch and cullet in a shorter portion of the furnace and decreases dust entrainment of the batch components in the regenerator checkerwork;

– equipping furnaces with efficient fuel-combustion systems ensuring the required degree of mixing of fuel and air,

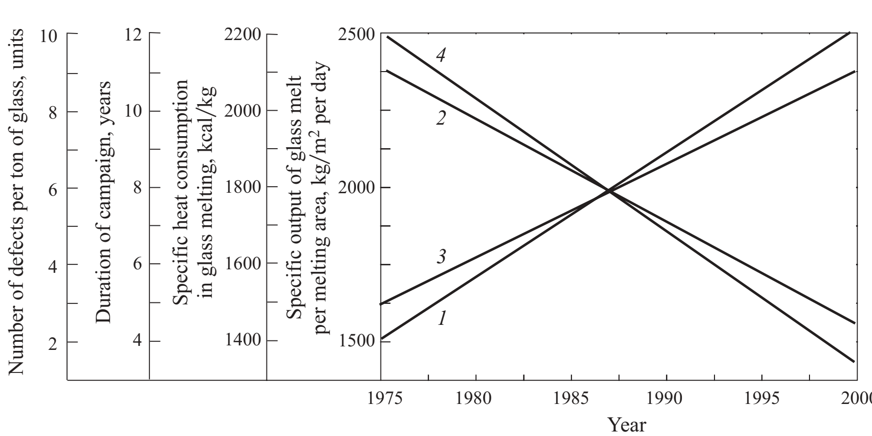

Fig. 1. The main technical and economic parameters of glass-melting tank furnaces for sheet float-glass in the past 30 years: *1*) specific output of glass melt per melting area; *2*) specific heat consumption in glass melting; *3*) campaign duration; *4*) number of defects per ton of glass.

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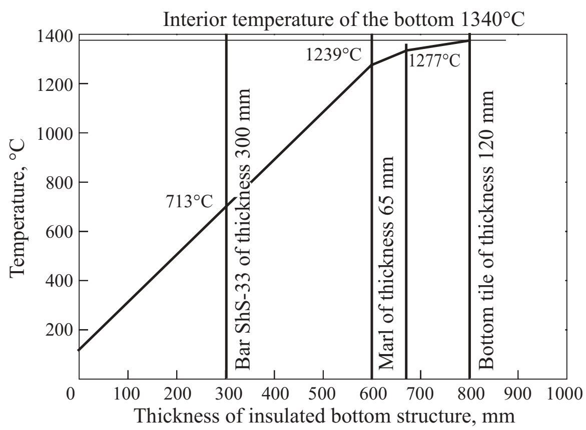

Fig. 2. Temperature distribution across the thickness of the heat-insulated bottom of the melting tank.

the maximum covering of the glass melt surface by the flame, and the possibility of adjusting the flame length under any thermal load while preventing excessive leaps of the flame;

– equipping furnaces with high-precision automated control systems for regulation of the fuel : air ratio ensuring technologically justified coefficients of air excess in all the burners of the furnace.

Note that such systems currently used in the domestic glass industry do not allow for maintaining this ratio with a sufficient accuracy. According to our data, increasing the quantity of air supplied for combustion by 1% increases the fuel consumption by 0.3 – 0.4%, other terms being equal. In our opinion, the furnace should be equipped as well with instruments for controlling air excess coefficients for particular burners, for instance, by measuring the content of oxygen in waste gases and possibly using these data in the automated control system for adjusting the fuel : air ratio.

Naturally, the work carried out at the Salavatsteklo company is not limited to the above listed systems for furnace operation. We will continue upgrading the batch preparation technology, mainly, expanding the range of available materials, optimizing the granulometric composition of materials (in particular, enlarging the size of dolomite and lime particles), and loading batches with a required degree of homogeneity, moisture, and temperature. The research oriented to a rational distribution of thermal loads along the melting zone, optimization of the glass melt bubbling process, etc., is being continued.

Based on the work experience and the current world trends, various technical solutions are proposed to improve the furnace design, including the overall dimensions of the furnace, the ratio between the melting and hot condition zones in the melting tank, the size of the neck and its equipment with cooling and mixing devices, the dimensions of the cooling tank, the need of using devices for heating and cooling of the glass melt in the cooling zone, and technical solutions intended to prevent the formation of glass melt stagnation zones.

The Salavatsteklo JSC has accumulated extensive experience in the rational use of refractories in the furnace brickwork, in optimum and reliable methods for heat insulation of virtually all structural elements of the brickwork, and hot repairs of the most wearing sites [1 – 3]. Note in particular, that the thermal insulation of the melting tank bottom designed by us has gained wide acceptance in the glass industry and has made it possible to do without systems of additional electric heating of glass melt in the loading hopper and in the quellpunkt without any negative effect on the furnace performance and without increasing fuel consumption in glass melting.

Figure 2 shows the temperature distribution across the thickness of a heat-insulated bottom in our design version. It is notable that the temperature of the bottom layer of the glass melt has sharply increased up to 1340°C while the maximum glass-melting temperature is 1600(– 10)°C and the external temperature of the bottom is 164°C. In these conditions the thermal losses via the bottom have decreased significantly (approximately 2.8 times) and the formation of a superchilled (“dead”) bottom layer is totally excluded, which significantly improves the homogenizing capacity of the furnace and the quality of glass manufactured. At the same time, to ensure the corrosion resistance and reliability of the tank bottom under perceptibly enhanced temperatures of its inner surface contacting with glass melt, the brickwork of the upper part of the bottom should be made of solid polished melted-cast bottom slabs and high-resistant marl. Nevertheless, this significant increase in the temperature of the bottom glass melt layer during more than seven years of service shows that the melting tank bottom structure should be fortified by using thicker bottom tiles made of high-quality melted-cast refractory and placing bars from chamotte with an increased aluminum content as the upper row of the tank bottom.

Considering the experience of the furnace performance with the view of further extending its production campaign to 10 – 12 years, the most wearing brickwork elements, which limit the campaign duration, have been identified. Such elements primarily include the burner units of the melting and maximum temperature units (as a rule, the first four pairs of burners out of total six pairs), the walls between them, the stringers and cheeks of the same four pairs of burners, the teeth along the specified zones, as well as regeneration chambers (inlet arches to the chamber, outer lateral and partitioning walls, and chamber roofs).

It should be noted that three structural elements usually regarded as the most wearable are excluded from the above list: the upper wall bars in the melting and maximum temperature zones of the tank, the main roof abutment termination in the same zones, and the face loading wall with built-in and divulged arches. As for the latter elements, the most advisable is using a J-shaped loading wall of a standard design, which is successfully used in float-glass furnaces abroad,

since the dinas brick is not capable of ensuring the service life of the face wall for more than 5 – 6 years. The problem of increasing the resistance and reliability of the roof abutment termination can be solved by using a special profiled dinas product DS-51 in the brickwork, since it well protects these sites from corrosion and tightly seals the clearance between the walls and the burner arches below and the roof abutments above.

Finally, the most complicated problem, i.e., increasing the resistance of the upper part of the tank walls at the glass-melt level can be solved by reliably covering these sites with solid all-polished plates of melted-cast refractory of thickness 75 – 100 mm, which is consecutively implemented first in one layer, then a second and, if necessary, a third layer. This does not mean doing without high-density palisade bars with an oriented shrinkage cavity for the tank walls, on the contrary, it corroborates the need of using these bars (in some sites solid bars without a shrinkage cavity) made of melted-cast baddeleyite-corundum refractories with 37 – 41% ZrO_2 content.

When glass-melting furnaces using these palisade bars for the melting tank walls function more than 5 – 6 years, active corrosion sometimes leads to the substantial destruction of these bars along their total height. Therefore, it appears necessary to cover the melting tank walls (on the sites of intense corrosion) by plates made of high-quality melted refractory along the total height of the palisade bars, whereas at the level of the glass melt surface such plates should be contain 37 – 41% ZrO_2.

A long-time service life of the specified upper structure elements (burner units, intermediate walls, burner stringers and cheeks, inlet arches of the regenerator) is ensured by making them from melted-cast refractories that reliably prevent their destruction in the course of a long furnace campaign, which makes it possible to exclude them from the list of elements limiting the campaign.

The most complicate problems related not only to a reliable service, but also to the thermal and technological efficiency of the furnace in general, is the design of regenerators and the rational use of refractories in particular zones of the brickwork, especially checkerwork.

It is convenient to divide the regenerator checkerwork into four zones based on the degree and the type of the corrosion effect. The first topmost zone (3 – 5 upper rows) is mainly subjected to the effect of high-temperature (1500 – 1600°C) waste flue gas enriched with volatile solid batch components (alkali-earth metal carbonates, fine quartz sand fractions) and the products of fuel combustion (in particular, insignificant in their quantities, but very aggressive nickel and vanadium oxides). The refractories of the second (middle) zone (50 – 60% of the total checkerwork volume) at a temperature of 1450 – 1100°C are mainly affected by aggressive gaseous products formed in glass melting and fuel combustion. The third (the most critical) part known as the sulfate zone (30 – 40% of the total checkerwork volume) at 800 – 1100°C is subjected to an extremely aggressive effect of the sulfates of alkali and to a lesser extent alkali-earth metals condensing on the surface of the checkerwork. Finally, the fourth (the lowest) checkerwork zone located on the arches beneath the checkerwork (4 – 5 rows) at a temperature below 750°C is mainly subjected to thermal cycling and to a lesser extent to the effect of sulfate compounds.

Refractory materials selected for the specified checkerwork zones and for the respective sites of the walls and the roof of the regeneration chamber, considering the total destruction of dinas brickwork within 4 – 5 years, should be resistant and capable of ensuring long-term service without hot repairs in the particular conditions of each brickwork zone. As can be seen from corrosion tests and the practical experience of various types of glass-melting furnaces, the most suitable refractories for regenerator checkerwork are fired periclase (with MgO content at least 97%) and periclase-zirconium materials, as well as melted-cast baddeleyite-corundum and spinel materials. The rational use of these refractories (for checkerwork shaped as profiled cruciform or dish-shaped products) makes it possible not only to exclude the regenerator from the list of the elements limiting the furnace campaign, but also to increase the overall thermal efficiency of the furnace due to reducing fuel consumption by at least 10%.

Thus, the performance of contemporary glass-melting tank furnaces in the Russian Federation, taking into account the domestic and foreign experience and high requirements of the contemporary market imposed on the quality, product range, and technical parameters of sheet glass, requires a comprehensive approach to the design and construction of highly efficient sheet-glass furnaces of a new generation.

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